DOCUMENT RESUME

ED 138 371 PS 009 249

AUTHOR Schmidt, Constance R.; Paris, Scott G.
TITLE Children's Understanding of Causal Sequences.
PUB DATE Mar 77
NOTE 7p.; Paper presented at the Biennial Meeting of the Society for Research in Child Development (New Orleans, Louisiana, March 17-20, 1977)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *Age Differences; *Cognitive Development; *Early Childhood Education; Elementary School Students; Kindergarten Children; *Memory; Pictorial Stimuli; Preschool Children; Research; *Sequential Learning
IDENTIFIERS *Causal Relationships; Piaget (Jean)

ABSTRACT

This series of four experiments on children's causal sequences was directed at: (1) extending Brown's research on temporal ordering to causal relationships portrayed in picture sequences; (2) investigating the developmental progression of skills involved in understanding and remembering sequences; and (3) examining the development of reversible thinking about causal sequences. Subjects were preschool, kindergarten and second grade children. All studies employed the same six sets of pictures. Each set contained eight pictures, a four-item causal sequence and four distractors. In general data suggest that there is a developmental progression in children's ability to operate with causal sequences: initially children can rearrange elements of a sequence; subsequently they can select and construct sequence components from a distracting array; and finally they can develop reversible operations in reconstruction of causal order. (MS)

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Paper presented at the bienniel meeting of the Society for Research in Child Development, New Orleans, 1977

Children's Understanding of Causal Sequences

Constance R. Schmidt and Scott G. Paris
Purdue University

In order to remember temporal and causal sequences, one often needs to infer and integrate the connections among component events. Fraisse (1963) suggested that adults rely on inferential processes in order to produce and reconstruct an ordered series. However, both Fraisse (1963) and Piaget (1969) have argued that young children cannot reproduce ordered sequences because they cannot comprehend the relationships inherent in the sequences. To do so would require a sophisticated, reversible concept of order - a concept that does not develop until the period of concrete operations.

However, preoperational children's failure to reconstruct ordered sequences may be due partly to their poor expository skills on verbal tasks. Brown and her associates have shown that preoperational children can construct, reconstruct, and recognize temporal sequences in pictorial tasks even though they have difficulty recounting sequences verbally. Apparently, young children can remember pictures with logical connections as they reconstruct temporal sequences. This finding may indicate that reversibility of the concept of order is not a prerequisite for children's comprehension and reconstruction of temporally ordered events. In fact, Brown and French (1976) observed that six-year olds displayed a unidirectional ability to construct sequences. Given the initial events of a series the children readily supplied the terminal events, but they had difficulty moving from the end of a sequence back to the beginning events.

The present research was directed at three major issues. First, we wanted to extend Brown's research on temporal ordering to causal relationships portrayed in picture sequences. Our pictorial sequences contained cause-effect relationships as well as temporal orderings of events. By maximizing the sequential connections between events, we hoped to provide children with ample opportunity to recognize the most probable order of events. Our second purpose was to investigate the developmental progression of skills involved in understanding and remembering sequences. From our pilot work, we hypothesized that young children might be able initially to rearrange a scrambled sequence, later to select sequential items from an array of correct and inappropriate pictures, and, at a somewhat later age, to remember and infer correct sequences of pictures. Eventually, children should be able to combine these skills in order to reason from causes to effects and backwards from effects to causes. Our third concern in this set of studies, then, was to examine the development of reversible thinking about causal sequences.

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In the present paper, we would like to present the results of four of our studies concerning these developmental issues. All studies employed the same six sets of pictures. Each set contained eight pictures, a four-item

causal sequence and four distractors. An example is provided in Figure One. Note that the relationship between the antecedent events and the final picture is one of necessary causation-a tree that is midair nearly always falls to the ground. All sequences were based on similar physical laws of causality. The distractor pictures were designed to include the same characters and settings as the sequences. However, the distractor pictures could not be appropriately inserted into the immediate chain of action.

Experiment I tested children's ability to rearrange the four pictures into the correct order. Twelve preschoolers ($\overline{CA}$ = 5 yrs 0 mos) and 12 kindergarten children ($\overline{CA}$ = 5 yrs 10 mos) were presented each four-picture sequence in a scrambled order and asked to arrange the sequence in the order that "made the best story." As a group, the kindergarteners correctly rearranged 78% of the sequences while preschoolers were correct on only 37% of the sequences. Performance at both age levels was significantly greater than chance. Each child could rearrange from zero to five sequences correctly. The mean-scores for preschoolers and kindergarteners were 1.83 and 3.92, respectively. The difference between the means was significant at the .05 level ($t(22) = 2.81$). Four, five, and six year olds in Experiment I could rearrange sequential items in the correct order and sequencing ability improved over this age range.

In Experiment II, we asked children to select four picutres from an array of all eight pictures and then to construct "the best story." Selection from among distractors and subsequent construction proved to be a more difficult task than simple rearrangement of the four pictures into the correct order. We tested 15 kindergarteners ($\overline{CA}$ = 5 yrs 11 mos) and 15 second-graders ($\overline{CA}$ = 8 yrs 4 mos) on this task. One criterion for correct performance, the one that we will report here, is correct selection and placement of either three or four sequence pictures. As you can see in Table 1, kindergarteners were correct on 16% of the sequences and second-graders were correct on 76% of the sequences. Both levels of performance significantly exceeded chance expectation. The mean numbers of sequences correctly constructed by each age level were .80 and 3.80, respectively, and this difference was significant at the .01 level ($t(28) = 7.83$). Scanning the array of eight pictures, selecting four items for the story, and placing them in a correct sequence was a more difficult task than the rearrangment task employed in Experiment I. Yet five and six year olds succeeded on some occasions and second-graders could select and order the items on a majority of the sequences.

We were also interested in determining the developmental skills involved in remembering and inferring items in causal sequences. In Experiment III, five incomplete picture sequences were presented to children. The first three pictures of each sequence were shown to subjects who were asked to remember them. Subjects in this study were 16 preschoolers($\overline{CA}$ = 4 yrs 11 mos), 16 kindergarteners ($\overline{CA}$ = 5 yrs 11 mos), and 16 second-graders ($\overline{CA}$ 8 yrs 2 mos). Following presentation of all five incomplete sequences and a brief interpolated activity, children were given a 3 AFC recognition test. There were

10 trials in the memory test, two items for each sequence. One type of test item included the first picture of each sequence and two distractor pictures. The other type of test item included the final picture or consequence of each sequence and the other two distractors for the sequence. In other words, one type of item assessed children's memory for an old, previously seen picture, and one type of item assessed children's ability to infer a reasonable consequence to the sequence. The test instructions directed children to select the picture that "went with" one of the initial stories whether they had actually seen the exact picture or not. Selecting the correct consequence requries both memory for the original sequence and inferential abilities to determine a plausible consequence. The mean numbers of trials correct, out of 10, were 5.81, 7.25, and 8.94 for each age level. The percentages of correctly identified antecedents (old items) and consequences (inferred items) are shown in Table 2. Even the preschoolers' performance levels were above chance for identifying old pictures and inferring new consequences (X^2 (1) = 25.59, $p < .01$; X^2 (1) = 18.90, $p < .01$). An Age (3) x Test Item (2) ANOVA performed on the data in Table 2 revealed a significant main effect of age only ($F(2,45) = 12.20$, $p < .01$). The consistent superiority of old items over implied consequences did not reach significance ($F(1,45) = 3.28$, $p < .10$). It is important to note, though, that four and five year olds could remember and infer sequential items at better than chance levels and the abilities to recall and reason from the original incomplete sequences improved with age.

The ability to infer consequences from sequences suggests that children can operate in a forward direction with sequences, but can young children also operate in the other direction and infer antecedents to a given consequence? Experiment IV was designed to answer this question in a within-subjects design. Six incomplete picture sequences were presented to children. Three of the sequences included the first three pictures of each story, as in Experiment III, and three other sequences included the final three pictures. In other words, for half of the presented sequences the initial picture was absent and we could determine children's abilities to infer a plausible antecedent to the depicted consequence. The subjects in this study were 12 preschoolers ($\overline{CA}$ 4 yrs 10 mos) and 12 kindergarteners ($\overline{CA}$ 5 yrs 8 mos).

The procedure included a 3 AFC recognition test and was similar to that of Experiment III. The results are shown in Table 3. The performance of both preschoolers and kindergarteners exceeded chance on both antecedent and consequence test items (X^2 (1) = 7.56, $p < .01$, X^2 (1) = 45.56, $p < .01$). An Age (2) x Type of Item (Old, New) (2) x Antecedent-Consequence (2) ANOVA of this data revealed significantly better performance by kindergarten children ($F(1,22) = 10.02$, $p < .01$) and significantly better performance on consequence items ($F(1,22) = 6.03$, $p < .05$). We were struck by the fact that even five year olds could remember and infer sequential events although the ability to do so improves with age. The results also indicate that there is an asymetry in the preoperational child's ability to deal with causal sequence. It is more difficult for five and six year olds to identify the antecedent of a sequence when given the terminal events than it is for them to identify the

consequence when given initial events. We plan to administer the task employed in Experiment V to first and second graders to determine if and when the asymetry in direction of understanding is eliminated.

In general, the series of experiments we have discussed confirm and extend the investigations of Brown and her associates. The data from the four experiments suggest that there is a developmental progression in the ability to operate with causal sequences. Initially, children can rearrange elements of a sequence, subsequently, they can select and construct sequence components from a distracting array. Finally, children develop reversible operations in reconstruction of causal order. Concurrently, the ability to remember and infer components of causal sequences develops. This progression is consistent with the progression in understanding of temporal sequences from recognition to reconstruction to recall reported by Brown (1975). Also, the asymetry in direction of operativity found by Brown and French (1976) using temporal sequences was replicated in Experiment IV using causal sequences. It is important to note, however, that although preoperational children do not possess a concept of order that is completely reversible, they are capable of inferring the antecedent of a sequence when given the terminal events with a surprising degree of accuracy. As Brown (1975) has noted, there seems to be a period of "semilogical" operations in dealing with ordered sequences during which young children can construct, reconstruct, and recognize ordered sequences but their ability tends to be asymetric with respect to direction of understanding and is limited when verbal assessments of comprehension are employed.

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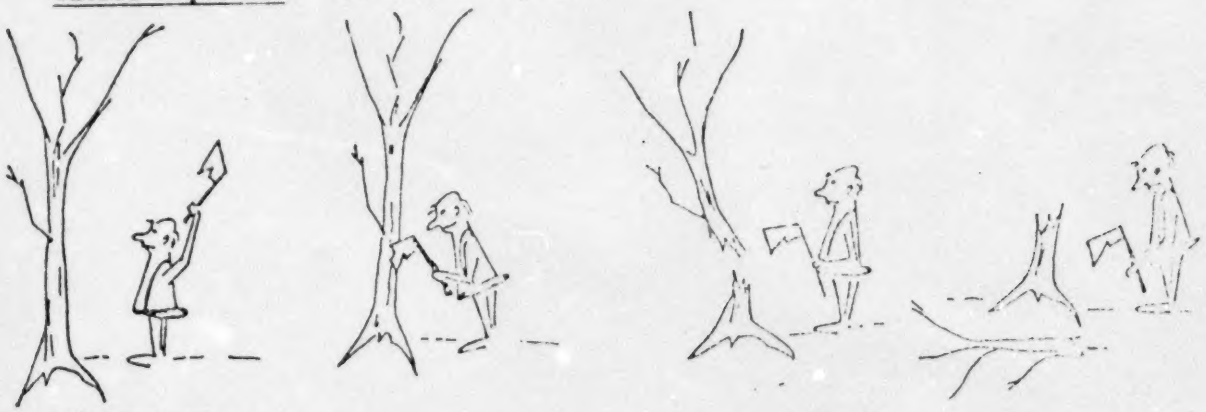
Figure One

Causal Sequences: Woodcutter Sequence



Distractors

The remaining five sequences protrayed, (1) a man diving off a diving board, (2) a man throwing a pie into another man's face (3) a man tripping over a roller skate, (4) a man falling into a hole, and (5) a boy lighting a campfire.

Table 1

Percentages of Sequences Correctly Constructed in Exps. I and II

Grade	Construction Without Distractors (Exp. I)	Construction With Distractors (Exp. II)
Preschool	37	-
Kindergartern	78	16
Second	-	76

Table 2

Percentages of Antecedents and Consequents Correctly Identified in Exp. III.

	Recognition Item	
Grade	Antecedents	Consequents
Preschool	60.0	56.3
Kindergarten	77.5	67.5
Second	95.0	84.0

Table 3

Percentages of Antecedents and Consequents Correctly Identified on Memory (Old) and Inference (New) Items in Exp. IV

	Type of Item			
	Memory (Old)		Inference (New)	
Grade	Antecedents	Consequents	Antecedents	Consequents
Preschool	50	75	47	67
Kindergarten	83	92	75	75